

motions arrived at by the comparison of a large number of "snap" pictures. The insect was in each case placed on a white ground within a shallow box covered with glass and illuminated by oblique sunlight. In this way the disposition of the shadows became of great service in determining the positions of the legs.

Attractive Characters in Fungi.

No doubt the characters of the fungi mentioned by Mr. C. R. Straton on p. 9 are attractive, but it does not follow that they are useful. Mr. Straton's letter contains many incorrect statements: the importance of colours and odours to flowering plants cannot be correctly said to be "perfectly understood"; fungi are not "insusceptible of fertilization"; the common mushroom has no "parasitic period," and the first stage of its existence is not "passed in the body of an animal host."

The common mushroom never grows on the droppings of the horse, or upon the droppings of any other animal, and it cannot even be made to grow artificially upon fresh dung. An admixture of earth with decayed dung is required before mushrooms will grow. The mushroom is not a dung-borne fungus at all. It grows in pastures in common with a vast number of other pasture-fungi, and if we allow that the spores of the mushroom must needs first germinate in an animal stomach, it would be but reasonable to assume that the spores of other pasture-fungi would have a similar habit. The mycelium so commonly seen on horse dung is not the mycelium of the mushroom; it belongs to various dung-borne *Coprin*i, and it is certainly not necessary for the spores of these *Coprin*i to pass through a horse's intestinal canal, as they will readily germinate, not only on and in dung and its juices, but on wet blotting-paper, and on almost any other non-corrosive damp and warm material.

Mr. Straton seems to have a remarkable idea of the nature of a "parasite"; because an animal swallows spores, therefore the spores on being swallowed become "parasites." He might as reasonably describe the seeds eaten by graminivorous animals as "parasites," or the seeds of the strawberry and raspberry, when eaten with the pulp by man, as "parasites" in the human system.

As Dr. Cooke, in his interesting letter on p. 57, has not mentioned one special character of certain fungi which has greatly interested me, I may venture to advert to it here. I refer to *gluten*. Many fungi, especially Agarics, are highly glutinous, and if this gluten is not "attractive," it is, I think, useful.

Agaricus radicans is one of our commonest stump-fungi; it has, when young, a perfectly dry pileus. As the fungus reaches maturity, the pileus becomes glutinous. The change reminds one of the change in the condition of the stigma in flowering plants. If sections are made through the pileus of *A. radicans* in different stages of growth, it will be found that as maturity is gradually reached the centre of the pileus softens and swells, and through the now soft mass an enormous number of cystidia protrude themselves. The cystidia exactly resemble the cystidia of the gills. The cystidia open at the apex, and gluten exudes through the open mouths on to the cap of the fungus. If the sticky material from a mature example is microscopically examined, it will be found more or less full of germinating spores, which have been wafted on to the sticky pileus by the wind. The gluten possibly aids germination, if it does not—as I believe it does—cause fertilization.

Agaricus mucidus has a highly glutinous pileus, and it grows in such a fasciculate and closely imbricated manner on beech trunks, that all the spores from the upper examples fall of necessity on to the thick gluten of the examples immediately underneath. If the gluten is microscopically examined, it will be found full of the germinating spores of *A. mucidus*. The uses of the gluten here seem obvious. The simple spores of an Agaric might have but a poor chance of effectually germinating and growing upon a beech trunk, but if the spores had previously germinated and formed a mycelium in a highly glutinous material, they would have a fairly good chance. The sticky pileus would at length be blown from the beech trunk by the wind, and its mucidous character would cause it to stick to the first trunk or branch it might be blown against, and so the gluten and its living mycelium would become attached to a fresh host. *A. mucidus* is peculiar to beech woods.

I could extend these notes to other gluten-bearing fungi, as *A. adiposus*, &c., as well as to Agarics with glutinous stems; but

the two examples above given may serve as a hint to other observers.

How have truffles acquired their subterranean habit? They are always eagerly eaten by pigs, squirrels, rats, and other animals when they grow near the surface, and the deeper placed examples alone survive. Would the constant destruction of tubers near the surface at length bring about a subterranean habit?

WORTHINGTON G. SMITH.

Dunstable.

UNDOUBTEDLY there are numerous glutinous fungi, and the coating of gluten has a useful purpose. Whether Mr. Worthington Smith has quite apprehended the nature of that purpose may be an open question. The majority of the species in the genus *Hygrophorus* are glutinous, and this genus, as a whole, is about the latest in its time of appearance in the autumn. It is very suggestive to observe them apparently unharmed by frost, whilst the Agarics have collapsed, and are in rapid decay. That the glutinous coating is in this instance a protection from frost can scarcely be denied. Dr. Quelet, the French mycologist, has stated that in the Vosges some species of *Hygrophorus* do not appear until the early frosts have commenced, and he has borne testimony to the fact that they flourish in frosty weather without apparent injury. Both the species of Agaric to which Mr. Smith alludes, *Agaricus mucidus* and *Agaricus radicans*, may be found late in the season, apparently indifferent to the frost, which affords a suspicion that the glutinous coating is a protection from frost. *Agaricus carbonarius* is viscid, but much more so as cold increases, and for two consecutive years we have watched it growing uninjured far into January, when no other Agaric could be seen. We do not contend that the "useful purpose" is in all cases a protection from frost, because in some early species we imagine it serves primarily as a protection against evaporation. Presuming that Agarics may contain more than 80 per cent. of water, such a protection would be of service to species growing in exposed situations. If Mr. Smith's suggestion as to *Agaricus mucidus* is accepted, it can only apply to that species, and *Agaricus adiposus*, and one or two others, as the majority of tufted species growing on trunks are not glutinous. Another explanation must be found for the whole *Myxarium* section of *Cortinarius*, for *Gomphidius*, for many of the *Boleti*, and for such Agarics as *Agaricus aeruginosus*, *Agaricus semiglobatus*, *Agaricus lentus*, *Agaricus glutinosus*, *Agaricus roridus*, and many others. The idea that gluten "causes fertilization" is a novel one, and may be held as a private opinion, but cannot be accepted generally without evidence much stronger than individual belief; hence, although put forward by so experienced a mycologist as Mr. Worthington Smith, it must not be accepted as an admitted fact, but only as an individual opinion.

M. C. COOKE.

THE RESEARCHES OF DR. R. KENIG ON THE PHYSICAL BASIS OF MUSICAL SOUNDS.¹

II.

SO far we have been dealing with primary beats and beat-tones; but there are also secondary beats and secondary beat-tones, which are produced by the interference of primary beat-tones. An example of a secondary beat is afforded by the following experiment. Recurring to the preceding table of experiments, it may be observed that when the two shrill notes, *ut*₆, *sol*₆, giving the interval of the fifth, are sounded together, the inferior and superior beat-tones are both present, and of the same pitch. If, now, one of the two forks is lightly loaded with pellets of wax to put it out of adjustment, we shall get beats, not between the primary tones, but between the beat-tones. Suppose we add enough wax to reduce the vibration of *sol*₆ from 3072 to 3070. Then the positive remainder is 1022, and the negative remainder is 1026; the former being *ut*₃ flattened two vibrations, the latter the same note sharpened to an equal amount. As a result there will be heard four

¹ By Prof. Silvanus P. Thompson. (Communicated by the author, having been read to the Physical Society of London, May 16, 1890.) Continued from p. 203.

beats per second—secondary beats. Similarly, the intervals 2 : 5, 2 : 7, if slightly mistuned, will, like the fifth, yield secondary beats. Or, to put it in another way, there may be secondary beats from the (mistuned) beat-tones that are related (as in our experiment) in the ratio 1 : 1, or in the ratios 3 : 4, 3 : 5, &c., and even by those of 1 : 2, 4 : 5, 4 : 7, and so forth.

I have given you an example of secondary beats : now for an example of a secondary beat-tone. This is afforded by one of the previous experiments, in which were sounded ut_6 and the 11th harmonic of ut_3 . In this experiment, as in that which followed with the 13th harmonic, two (primary) beat-tones were produced, of 768 and 1280 vibrations respectively. These are related to one another by the interval 3 : 5. If we treat these as tones that can themselves interfere, they will give us for their positive remainder the number 256, which is the frequency of ut_4 . As a matter of fact, if you listen carefully, you may, now that your attention has been drawn to it, hear that note, in addition to the two primary tones and the two beat-tones to which you listened previously.

In von Helmholtz's "Tonempfindungen," he expresses the opinion that the distinctness with which beats are heard depends upon the narrowness of the interval between the primary tones, saying that they must be nearer together than a minor third. But, as we have seen, using bass sounds of a sufficient degree of intensity and purity, as is the case with those of the massive forks, beats can be heard with every interval from the mistuned unison up to the mistuned octave. Even the interval of the fifth, ut_4 to sol_1 , gave strongly-marked beats of 32 per second. When this number is attained or exceeded, the ear usually begins to receive also the effect of a very low continuous tone, the beats and the beat-tone being simultaneously perceptible up to about 60 or 70 beats, or as a roughness up to 128 per second. If, using forks of higher pitches but of narrower interval, one produces the same number of beats, the beat-tone is usually more distinct. Doubtless this arises from the greater true intensity of the sounds of higher pitch. With the object of pursuing this matter still more closely, Dr. Koenig constructed a series of 12 forks of extremely high pitch, all within the range of half a tone, the lowest giving si_6 and the highest ut_7 . The frequencies, and the beats and beat-tones given by seven of them, are recorded in Table III.

TABLE III.

Frequencies of Forks.	Ratio.	Beats (Calcd.)	Resulting Sound.
ut_7 } and si_6 } 4096 }	16 : 15	256	ut_3
" 3840 ...	32 : 31	128	ut_2
" 4032 ...	64 : 63	64	ut_1
" 4048 ...	256 : 253	48	sol_{-1}
" 4056 ...	512 : 507	40	mi_{-1}
" 4064 ...	128 : 127	32	ut_{-1}
" 4070 ...	158 : 157	26	—

The first of these intervals is a diatonic semitone ; the second of them is a quarter-tone ; the third is an eighth of a tone ; nevertheless, a sensitive ear will readily detect a difference of pitch between the two separate sounds. The last of the intervals is about half a comma.

These forks are excited by striking them with a steel hammer. Some of the resulting beat-tones will be heard all over the theatre ; but, in the case of the very low tones of 40 and 32 vibrations, only those who are close at hand will hear them. The case in which there are 26 beats is curious. Most hearers are doubtful whether they perceive a tone or not. There is a curious *fluttering* effect, as though a tone were there, but not continuously.

We have seen, then, that the beat-tones correspond in

pitch to the number of the beats ; that they can themselves interfere, and give secondary beats ; and that the same number of beats will always give the same beat-tone irrespectively of the interval between the two primary tones. What better proofs could one desire to support the view that the beat-tones are caused, as Dr. Young supposed, by the same cause as the beats, and not, as von Helmholtz maintains, by some other cause? Yet there are some further points in evidence which are of significance, and lend additional weight to the proofs already adduced.

Beats behave like primary impulses in the following respect, that when they come with a frequency between 32 and 128 per second, they may be heard, according to circumstances, either discontinuously or blending into a continuous sensation.

It has been objected that, whereas beats imply interference between two separate modes of vibration arising in two separate organs, combination-tones, whether summational, or differential, or any other, must take their origin from some one organ or portion of vibratile matter vibrating in a single but more complex mode. To this objection an experimental answer has been returned by Dr. Koenig in the following way. He takes a prismatic bar of steel, about 9 inches in length, and files it to a rectangular section, so as to give, when it is struck at the middle of a face to evoke transversal vibrations, a sound of some well-defined pitch. By carefully adjusting the sides of the rectangular section in proper proportions, the same steel bar can be made to give two different notes when struck in the two directions respectively parallel to the long and short sides of the rectangle. A set of such tuned steel bars are here before you. Taking one tuned to the note $ut_6 = 2048$, with $re_8 = 2304$, Dr. Koenig will give you the notes separately by striking the bar with a small steel hammer when it is lying on two little bridges of wood, first on one face, then on the other face. If, now, he strikes it on the corner, so as to evoke both notes at once, you immediately hear the strong boom of $ut_3 = 256$, the inferior beat-tone. If Dr. Koenig takes a second bar tuned to ut_6 , and $si_6 = 3840$, you hear also ut_3 , this time the superior beat-tone. If he takes a bar tuned to ut_6 and the 11th harmonic of ut_3 (in the ratio 8 : 11), you hear the two beat-tones sol_4 and mi_5 (in ratios of 3 and 5 respectively) precisely as you did when two separate forks were used instead of one tuned bar.

Dr. Koenig goes beyond the mere statement that beats blend to a tone, and lays down the wider proposition that any series of maxima and minima of sounds of any pitch, if isochronous and similar, will always produce a tone the pitch of which corresponds simply to the frequency of such maxima and minima. A series of beats may be regarded as such maxima and minima of sound ; but there are other ways of producing the effect than by beats. Dr. Koenig will now illustrate some of these to you.

If a shrill note, produced by a small organ-pipe or reed, be conveyed along a tube, the end of which terminates behind a rotating disk pierced with large, equidistant apertures, the sound will be periodically stopped and transmitted, giving rise, if the intermittences are slow enough, to effects closely resembling beats, but which, if the rotation is sufficiently rapid, blend to a tone of definite pitch. Dr. Koenig uses a large zinc disk with 16 holes, each about 1 inch in diameter. In one set of experiments this disk was driven at 8 revolutions per second, giving rise to 128 intermittences. The forks used were of all different pitches from $ut_3 = 256$ to $ut_7 = 4096$. In all cases there was heard the low note ut_2 corresponding to 128 vibrations per second. In another series of experiments, using forks ut_2 and ut_3 , the number of intermittences was varied from 128 to 256 by increasing the speed, when the low note rose also from ut_2 to ut_3 .

From these experiments it is but a step to the

next, in which the intensity of a tone is caused to vary in a periodic manner. For this purpose Dr. Kœnig has constructed a siren-disk (Fig. 1), pierced with holes arranged at equal distances around seven concentric circles; but the sizes of the holes are made to vary periodically from small to large. In each circle are 192 equidistant holes, and the number of maxima in the respective circles was 12, 16, 24, 32, 48, 64, and 96. On rotating this disk, and blowing from behind through a small tube opposite the outermost circle, there are heard, if the rotation is slow, a note cor-

responding to the number of holes passing per second and a beat corresponding to the number of maxima per second. With more rapid rotation two notes are heard—a shrill one, and another 4 octaves lower in pitch, the latter being the beat-tone. On moving the pipe so that wind is blown successively through each ring of apertures, there is heard a shrill note, which is the same in each case, and a second note (corresponding to the successive beat-tones) which rises by intervals of fourths and fifths from circle to circle.

These attempts to produce artificially the mechanism

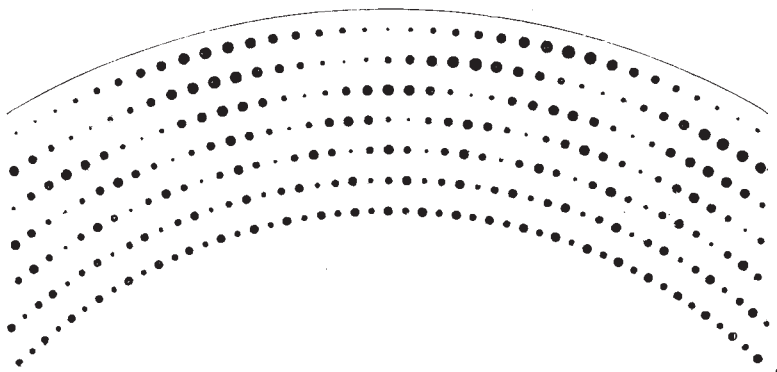


FIG. 1.

of beats were, however, open to criticism; for in them the phase of the individual vibrations during one maximum is the same as that of the individual vibrations in the next succeeding maximum; whereas in the actual beats produced by the interference of two tones the phases of the individual vibrations in two successive maxima differ by half a vibration; as may be seen by simple inspection of the curves corresponding to a series of beats. When this difference was pointed out to Dr. Kœnig, he constructed a new siren-disk (Fig. 2), having a similar series of holes of varying size, but spaced out so as to corre-

spond to a difference of half a wave between the sets. With this disk, beats are distinctly produced with slow rotation, and a beat-tone when the rotation is more rapid.

Finding this result from the spacing out of apertures to correspond in position and magnitude to the individual wavelets of a complex train of waves, it occurred to Dr. Kœnig that the phenomena of beats and of beat-tones might be still more fully reproduced if the edge of the disk were cut away into a wave-form corresponding precisely to the case of the resultant wave produced by

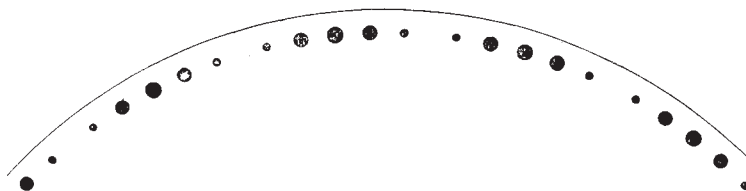


FIG. 2.

the composition of two interfering waves. Accordingly, he calculated the wave-forms for the cases of several

to the form of the desired wave. Two such wave-disks, looking rather like circular saws with irregular teeth, are

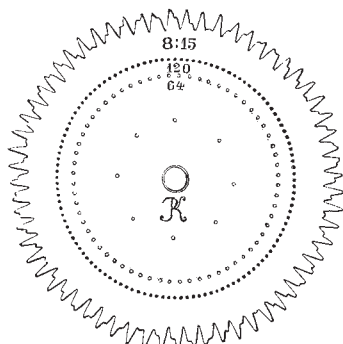


FIG. 3.

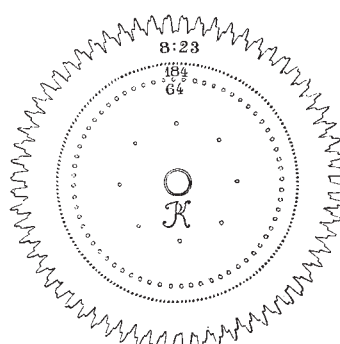


FIG. 4.

intervals, and, having set out these curves around the periphery of a brass plate, cut away the edge of the plate

depicted in Figs. 3 and 4. These correspond to the respective intervals 8:15 and 8:23. A number of such

wave-disks corresponding to other intervals lie upon the table; these two will, however, suffice. In the first of these the curve is that which would be obtained by setting out around the periphery a series of 120 simple sinusoidal waves, and a second set of 64 waves, and then compounding them into one resultant wave. In order to permit of a comparison being made with the simple component sounds, two concentric rings of holes have been also pierced with 120 and 64 holes respectively. Regarding these two numbers as the frequency of two primary tones, there ought to result beats of frequency 8 (being the negative remainder corresponding to the superior beat). An interior set of 8 holes is also pierced, to enable a comparison to be made. To experiment with such wave-disks they are mounted upon a smoothly running whirling-table, and wind from a suitable wind-chest is blown against the waved edge from behind, through a narrow slit set radially. In this way the air-pressures in front of the wave-edge are varied by the rush of air between the teeth. It is a question not yet decided how far these pressures correspond to the values of the ordinates of the curves. This question, which involves the validity of the entire principle of the wave-siren cannot here be considered in detail. Suffice it to say that for present purposes the results are amply convincing.

The wave-disk (Fig. 3) has been clamped upon the whirling-table, which an assistant sets into rotation at a moderate speed. Dr. Koenig blows first through a small pipe through one of the rows of holes, then through the other. The two low notes sound out separately, just a major tone apart. Then he blows through the pipe with a slotted mouth-piece against the waved edge; at once you hear the two low notes interfering, and making beats. On increasing the speed of rotation the two notes become shrill, and the beats blend into a beat-tone. Notice the pitch of that beat-tone: it is precisely the same as that which he now produces by blowing through the small pipe against the ring of 8 holes. With the other wave-disk, having 184 and 64 holes in the two primary circles, giving a wave form corresponding to the interval 8:23, the effects are of the same kind, and when driven at the same speed gives the same beat-tone as the former wave-disk. It will be noted that in each of these two cases the frequency of the beat-tone is neither the difference nor the sum of the frequencies of the two primary tones.

To be continued.)

DR. HENRY SCHLIEMANN.

THE death of Dr. Schliemann comes on his friends not only as a sorrow but as a surprise, for though he had tried his constitution, his strength was so great that it seemed equal to many more labours. He was essentially a self-made man, not merely as the architect of his own fortunes, but as having at an early age deliberately adopted certain purposes in life, and having accomplished them with astonishing success. These deliberate purposes made his career brilliant, and his character manly and sturdy.

In the preface to "Ilios" (1880) Schliemann gives a sketch of his early life and his excavations which reads like a romance. Before he was ten years old, he had made up his mind that the mighty walls of Troy could not have entirely disappeared, but must have been only buried by the dust of ages, and that he would himself some day bring them to light. But a romantic boyhood ended in a bitter struggle with poverty, until at one time he had to sell his last coat, and after shipwreck arrived at Amsterdam a penniless outcast. Obtain-

ing there a post worth £32 a year, he spent the half of that sum on living, and the other half on self-education, his dinner costing him twopence, and a fire being an unknown luxury. By sheer business talent he rose from this poverty to great wealth; but this has been done by hundreds of uninteresting men: the interesting thing about Schliemann is that he never looked on wealth save as a means for accomplishing his darling purposes. While never ceasing to pray that some day he might have the happiness of learning Greek, he began on modern languages, which he mastered one after another in an incredibly short space of time, learning not merely to read, but to write and speak fluently, Swedish, Polish, Russian, Arabic, and many other tongues.

In 1871, he began his career as an explorer by an attack on the hill of Hissarlik, where he expected to find the remains of the Troy of his early dreams. In the art of excavation he seems to have had no teacher, and there can be no doubt that he has opened a new era in that art through his scientific genius. Literary genius may be erratic and incalculable, but genius works in science through clear discernment of means and by infinite pains. Schliemann's method was simple—to remove all the earth of a site and pass it through a sieve, taking care that, though hundreds of hands were at work, every one worked as an immediate organ of his own intelligence and design. The quality of insight came in principally in the choice of sites.

Splendid as were the results of Schliemann's excavations at Hissarlik, at Mycenæ, and at Tiryns, both as regards the recovery of antiquities, and as regards the advancement of knowledge, scholars recognize that he was not to be followed in his interpretation of his own discoveries. His individuality was too strongly marked, his imagination too fervent, to allow him to walk safely in the narrow ways of archæological science. And as a man who was born a fighter, and thoroughly carried out the old rule as to loving one's friends and hating one's enemies, he could not be impersonal in the choice of theories. To the judgment of his allies he often gave way with a delightful simplicity and modesty, but to attack he was impervious. One of his most interesting appearances in London was when he came in hot haste from Athens, accompanied by Dr. Dörpfeld, at the invitation of the Hellenic Society, to meet in open debate the objections, which he characteristically called "calumnies," which some archæologists had brought forward against his theory in regard to the prehistoric palace at Tiryns. Though Schliemann was a decided believer in Providence, there was in him an immense force of tough old Teutonic heathenism.

Yet he was a man of the world, and cosmopolitan in a sense in which few can claim to be so, for in almost any country he could have made himself at home as an active citizen. His ideal was Greece, and he succeeded in a very difficult task by finding in modern Greece the materials for a splendid ideal, when worked up with traditions of ancient glory. In this respect he was a greater poet than Byron, who spoke of some modern Greeks as "craven crouching slaves." Athens has indeed good reason for the gratitude which has assigned him a public grave at Colonus. At Athens he will leave a great gap. His palace, reflecting in every corner his career and his enthusiasms, was a place where the most open hospitality was accorded to men of all nations. In the living-rooms were Homeric texts; the servants bore high-sounding Greek names; the basement rooms were full of the spoils of Troy; while on the summit stood replicas of celebrated Greek statues. The host poured forth the simplicity of his heart and the overflowings of his enthusiasm, talking with an unconventional plainness sometimes disconcerting to Western ladies. Not even Madame Schliemann, long as she has shared her husband's labours